RAILWAY ,BRIDGES AND TUNNELS

1. **CHAPTER-1**

RAILWAYS

INTRODUCTION

Railways have been an important part of our transport infrastructure since the 19th century, and their development has enabled the use of trains as an effective and efficient means of travel.

The emergence of railways from around the 1820's marked the beginning of the end for canals, as trains could carry more goods, more people and travelled much faster. The first steam locomotive to carry passengers began operation in 1825, designed by engineer George Stephenson, on a line between Stockton and Darlington.

Stephenson also developed the Liverpool and Manchester Railway (L&MR), a significant improvement on the first steam locomotive. 'The rocket', was much more efficient, producing more steam and with horizontal pistons directly driving the wheels. The L&MR opened in 1830.

Railways spread rapidly throughout the UK with the increased demand for coal and steel, and for distribution of things such as newspapers and post. The railways were built by 'navvies' who would dig foundations, lay stones and fix the track. Most of the work was done by hand, using a pick axe.

SYSTEMS OF RAILWAYS

1. Surface Railways
2. Elevated Railways
3. Under Ground railways

4- Tube Railways

Surface Railways

Surface railways are the cheapest and most extensively used form of railway service in the world. In such a system, the track is laid on a ground that has a suitable embankment or cutting, depending upon the topography of the area. Metropolitan railways use electric traction because of the following advantages.

(a) Electric traction does not pollute the environment.

(b) The acceleration and deceleration of trains is faster.

(c) Electric traction ensures the availability of power for improved and modern signalling.

(d) An electric locomotive can haul a train with the same efficiency in both the directions and there is no need for reversing the direction of the locomotive.

(e) This system uses special type of coaches called electric multiple units (EMUs), which can carry more traffic than conventional coaches.

Elevated Railways

An elevated railway (also known as an El rail, El train or simply an El for short, and, in Europe, as an overhead railway) is a rapid transit railway with the tracks above street level on a viaduct or other elevated structure (usually constructed of steel, concrete, or brick). The railway may be broad gauge, standard gauge, narrow gauge, light rail, monorail, or a suspension railway. Elevated railways are usually used in urban areas where there would otherwise be a large number of level crossings. Most of the time, the tracks of elevated railways that run on steel viaducts can be seen from street level.

Under Ground Railways

An underground system is defined as an electric railway public transport network (a metro or subway system) that runs both above and underground.

Tube Railways

The term tube railway may refer to:

- an atmospheric railway, a railway that uses differential air pressure to provide power for propulsion of a vehicle.
- an underground railway constructed in a circular tunnel by the use of a tunnelling shield.
- by extension of the previous definition, the London Underground, most (but not all) of whose lines are so constructed.

The advantages & disadvantages of railway transport.

Railway transport occupies a significant role in the transport system of a country because the development of trade, industry and commerce of a country largely depends on the development of railways.

Advantages:

i. It facilitate long distance travel and transport of bulky goods which are not easily transported through motor vehicles.

ii. It is a quick and more regular form of transport because it helps in the transportation of goods with speed and certainty.

iii. It helps in the industrialization process of a country by easy transportation of coal and raw-materials at a cheaper rate.

iv. It helps in the quick movement of goods from one place to another at the time of emergencies like famines and scarcity.

v. It encourages mobility of labour and thereby provides a great scope for employment.

vi. Railway is the safest form of transport. The chances of accidents and breakdown of railways are minimum as compared to other modes of transport. Moreover, the traffic can be protected from the exposure to sun, rain snow etc.

vii. The carrying capacity of the railways is extremely large. Moreover, its capacity is elastic which can easily be increased by adding more wagons.

viii. It is the largest public undertaking in the country. Railways perform many public utility services. Their charges are based on charge what the traffic can bear principles which helps the poor. In fact, it is a national necessity.

Disadvantages:

i. The railway requires a large investment of capital. The cost of construction, maintenance and overhead expenses are very high as compared to other modes of transport. Moreover, the investments are specific and immobile. In case the traffic is not sufficient, the investments may mean wastage of huge resources.

ii. Another disadvantages of railway transport is its inflexibility. It routes and timings cannot be adjusted to individual requirements.

iii. Rail transport cannot provide door to door service as it is tied to a particular track. Intermediate loading or unloading involves greater cost, more wear and tear and wastage of time. The time cost of terminal operations are a great disadvantage of rail transport.

iv. As railways require huge capital outlay, they may give rise to monopolies and work against public interest at large. Even if controlled and managed by the government, lack of competition may breed in inefficiency and high costs.

v. Railway transport is unsuitable and uneconomical for short distances and small traffic of goods.

vi. It involves much time and labour in booking and taking delivery of goods through railways ascompared to motor transport.

vii. Because of huge capital requirements and traffic, railways cannot be operated economically in rural areas. Thus, large rural areas have no railway even today. This causes much inconvenience to the people living in rural areas.

CHAPTER-2 RAILWAY SURVEY

Infuencing The Railways Route

Our industry is experiencing widespread change, driven by wide-ranging and varied influences.

With these changes come both opportunities and challenges, and SmartRail World has set out to identify some of these key trends to help you better shape your strategic, long-term planning.We asked experts, canvassed opinion on social media and discussed the area at the SmartRail global event series and have identified nine key trends. Some you will be familiar with, some less so.

1. Climate Change.

Rail networks have been designed and built using historical records of climate and weather events. Now with the 'Inconvenient truth' of climate change, these projections are no longer a reliable predictor. Even what sound like modest changes in the average temperature can translate to large and potentially dangerous shifts in climate and weather.

Flooding on the tracks north of MNRs Garrison Station, New YorkHigh temperatures can cause rail tracks to expand and buckle, and may lead to more regular repairs, speed restrictions, delays and disruption. Storms can damage or deposit debris on lines and at stations and floods or high-tides can submerge them as well. This is particularly true in underground tunnels as seen in New York after Hurricane Sandy.

The rail industry now has to plan for a different weather future, and build accordingly with a 'predict and prevent' ethos looking forward rather than back. Our networks, standards and systems now have to be built for the world of the 2050s and beyond, a world which could be very different.

2. Urban growth.

Today, 54 per cent of the world's population lives in urban areas, a proportion that is expected, according to United Nations figures to increase to 66 per cent by 2050. Projections show that urbanization combined with the overall growth of the world's population could add another 2.5 billion people to urban populations by 2050, with close to 90 percent of the increase concentrated in Asia and Africa.

The rapid pace of urbanisation puts added pressure on already strained infrastructure – anyone who travels at peak-time in a major city will attest to this. As a result infrastructure needs to be designed to be able to be able to absorb such growth, and be as efficient and rapid is possible. Along with the pressures, though come opportunities – the increased size of cities widens their power and tax base and enables a greater investment in public transport, an example being the Crossrail project currently underway in London (pictured above).

Hand in hand with the rising populations is the growth of megacities (those with over 10 million people) predominantly in Asia. As of 2015, there are 35 megacities in existence, in 1950 there was just one (New

York). The sheer size and complexity of these multiplying megacities gives rise to enormous challenges.

Meeting the challenges and opportunities of urban growth is one of the key themes of Smart Metro (incoporating the 9th Annual CBTC World Congress, which returns to Paris on 29th - 31st October 2018.

3. Rise of the start-ups

At the recent SmartRail Europe Congress in Amsterdam, the pace of change was a regular point of discussion across all the streams. Same as always right? Well it's always a key point in any project, but what is shifting the parameters of the discussion is the entry of small, lean start-ups into the industry. Without the baggage and legacy of larger traditional firms, they don't play the conventional rules of the business. Digital rather than physical solutions can be rolled out in days or weeks, not months or years. And the perennial issues of ticketing, overcrowding and train organisation are some of the issues in the sights of start-ups aided by a recent blooming in hackathons and a first rail accelerator opening in London.

In the rebuilding of New Orleans after Hurricane Katrina Lt. General Russel Honore famously told a subordinate who he viewed was moving too slowly, "You're looking at your calendar and I'm looking at my watch."

4. Digitisation takes over.

Closely connected to the development of the start-up community within rail is a widening digitalisation of the processes behind many of the key systems behind rail operations. The digital revolution arrived in rail later than in other industries, but is quickly becoming the establishment. Any commercially focussed railway is now able to utilise a host of digital initiatives. Amongst many areas is the Internet of Things (IoT) enabling on-board sensors to deliver real time analysis and monitoring, identify problems before they cause delays, facilitate automated and preventive maintenance and ensure dispatchers have an entirely accurate view of the train's location.

Digitisation is often made possible by the presence and use of Big Data, and to pick just one example, the commuter train network in Stockholm, Sweden is using a predictive model, called 'the commuter prognosis' that uses Big Data to visualize the entire commuter train up to two hours into the future. This enable a forecast of disruptions in the service, with the traffic control centre able to prevent the ripple effects that cause most delays. In the future the algorithm will be potentially adaptable for more types of public transportations and cities.

These issues will be discussed at our SmartTransit Congress which takes place in Philadelphia on October 23-25, 2018

5. New players offering integrated travel solutions.

Uber and rail - a growing relationship.A recent study prepared for the American Public Transportation Association (APTA) through the Transit Cooperative Research Program has revealed that the people using services like Uber and Lyft are actually more and not less likely to travel on public transport. The survey taken by 4,500 people in seven different US cities showed that 50% of people travelled by train and 45% used buses frequently. The study can be viewed as insight into the impact of ride-sourcing on public transport.

There are some who view the likes of Uber and Lyft as the solution to the first-mile / last-mile challenge and to help overcome the concern that potential riders avoid public transport because of difficulties getting to or from the train or metro. And instead they end up driving. Ride-sourcers can help solve this by offering the optimal combination of walking, transit and their own transport.

There's huge potential for rail and metro to partner with companies Lyft or Uber, but caution must also be maintained that they don't become more attractive than public transport. And the performance of rail and metro, particularly in payments and booking must be improved to head off any future threat.

6. Powered by different energy sources.

Environmental concerns (see also Climate Change), fears over energy security and the lowering costs of implementation mean that rail is looking at new ways of powering itself.

On the train itself, options for possible replacements for diesel include hydrogen and perhaps the most appealing, LNG, already being tested by some railways and offering a competitive price, and lower carbon emissions plus an established regulatory structure when compared to its fossil and renewable fuel rivals. Whilst Alstom is currently developing entirely new types of fuel cell trains which aim to be completely emission-free.

Stations themselves are also looking to be powered differently. In the USA, the renovated Yawkey Station near Fenway Park in Boston will become a "zero net energy" commuter rail station when construction is finished in 2017. Solar panels and a shared-use garage on which a solar photovoltaic power plant will be installed is designed to provide all the energy required to power the station.

7. The station becoming a destination.

St Pancras International, in LondonRail stations are changing. For a long time they appeared to be an after-thought for many train operators, designed simply to get as many passengers in and out as quickly and safely as possible, But no more. Stations are evolving and offering more to its passengers, making them a place to stay in and enjoy, an amenity all to itself, rather than a building to quickly head away from or arrive with little time to spare before catching a train. The central position of stations, also puts them at the heart of urban regeneration schemes and a crucial link between commercial, leisure and residential spaces.

Many stations at aiming to take advantage of the huge footfall they experience (and help pay for their investments) by developing a dazzling area of retail and catering outlets to serve every taste (and pocket).

Whilst ergonomic design is becoming an increasing factor in the planning of stations ensuring that large numbers of travellers can move freely and efficiently to, through and from a station is an essential to maintaining the operational effectiveness of the transport system as a whole. Station developments now consider ergonomic and human factors, in particular looking in a scientific way at people and their needs, and then providing analytical evidence based on psychological, behavioural and physical factors to improve experiences.

8. Long distance travel makes a return.

Air travel hasn't been kind to long-distance rail, with many classic lines now redundant or operating on a limited, nostalgia focussed basis. However, a number of factors are pushing its growth and are likely to over future years. Improvements to booking and ticketing allied with high-speed trains (see below) and on-board service are also widening the uptake of trains to travel across continents.

As one example cross-Channel high-speed train operator Eurostar will be running a service between London and Amsterdam in late 2017. And whilst the United States lags behind in these stakes, Amtrak and new entrants have ambitious plans. China and Japan, which have focused on building high-speed networks that can compete and beat air travel.

Another trend helping support long distance rail travel, is the growth of codesharing, long found in the aviation industry where a marketing arrangement is created with an airline placing its designator code on a flight operated by another airline and selling tickets for that flight in order to strengthen or expand their market presence and competitive ability. This is now being seen in an intermodal form in partnerships with the rail industry. This kind of link-up between airlines and rail lines, known formally as air-rail alliance or informally 'Rail & Fly' are increasingly popular.

9. High-Speed and Hyper-Speed Rail

For anyone reading this in the United Kingdom or California they will be well versed in arguments about the development of high-speed rail but we could soon be entering the world of hyper-speed rail travel. High-speed rail has already revolutionized national and international transportation in many parts of the world, in particular in Japan, China and continental Europe. And now plans are being developed to go even faster.

Few will have escaped the media coverage of Elon Musk's 'Hyperloop', a innovative new form of transportation, consisting of an elevated, reduced-pressure tube that contains pressurized capsules driven within the tube by a number of electric motors, Musk claimed it would "never crash, be immune to weather, go twice as fast as an airplane, four times as fast as a bullet train, and – to top it off – run completely on solar power." Whilst the Hyperloop may currently lack the financial or political will to make it a reality there's no doubt that super high-speed rail is a reality.

In China, the Shanghai Maglev Train has been in operation since 2003 and has been recorded at a top speed of 311 mph, Japan's famed bullet train, the Shinkansen runs on a high-speed network of over 1400 miles hitting speeds of up to 275mph and in Europe, France's TGV Réseau which generally runs at 199mph has been serving passengers since 1992. The slow but continued growth of High-Speed rail not only opens up a host of further technical developments but offers a strong countermeasure to other forms of transport.

Track Alignment

Track geometry is three-dimensional geometry of track layouts and associated measurements used in design, construction and maintenance of railroad tracks. The subject is used in the context of standards, speed limits and other regulations in the areas of track gauge, alignment, elevation, curvature and track surface. Although, the geometry of the tracks is three-dimensional by nature, the standards are usually expressed in two separate layouts for horizontal and vertical.

Layout

Horizontal layout

Horizontal layout is the track layout on the horizontal plane. This can be thought of as the plan view which is a view of a 3-dimensional track from the position above the track. In track geometry, the horizontal layout involves the layout of three main track types: **tangent track** (straight line), **curved track**, and track transition curve (also called **transition spiral** or **spiral**) which connects between a tangent and a curved track.

In Australia, there is a special definition for a **bend** (or a **horizontal bend**) which is a connection between two tangent tracks at almost 180 degrees (with deviation not more than 1 degree 50 minutes) without an intermediate curve. There is a set of speed limits for the bends separately from normal tangent track.

Vertical layout

Vertical layout is the track layout on the vertical plane. This can be thought of as the elevation view which is the side view of the track to show track elevation. In track geometry, the vertical layout involves concepts such as cross level, cant and gradient.

Reference rail

The reference rail is the base rail that is used as a reference point for the measurement. It can vary in different countries. Most countries use one of the rails as the reference rail. For example, the United States uses the reference rail as the **line rail** which is the east rail of tangent track running north and south, the north rail of tangent track running east and west, the outer rail (the rail that is further away from the center) on curves, or the outside rails in multiple track territory. For Swiss railroad, the reference rail for tangent track is the center line between two rails, but it is the outside rail for curved track.

Track Gauge

Track gauge or rail gauge (also known as track gage in the United States[5]) is the distance between the inner sides (gauge sides) of the heads of the two load bearing rails that make up a single railway line. Each country uses different gauges for different types of trains. However, the 1,435 mm (4 ft 8 1⁄2 in) gauge is the basis of 60% of the world's railways.

Transverse Elevation

Crosslevel (or 'cross level') is the measurement of the difference in elevation (height) between the top surface of the two rails at any point of railroad track. The two points (each at the head of each rail) are measured at by the right angles to the reference rail. Since the rail can slightly move up and down, the measurement should be done under load.

It is said to be zero crosslevel when there is no difference in elevation of both rails. It is said to be reverse crosslevel when the outside rail of curved track has lower elevation than the inside rail. Otherwise, the crosslevel is expressed in the unit of height.

The speed limits are governed by the crosslevel of the track. In tangent track, it is desired to have zero crosslevel. However, the deviation from zero can take place. Many regulations have specification related to speed limits of certain segment of the track based on the crosslevel.

For curved track, most countries use the term cant or superelevation to express the difference in elevation and related regulations.

Warp

Warp is the difference in crosslevel of any two points within the specific distance along the track. The warp parameter in the track geometry is used to specify the maximum in the crosslevel difference of the track in any segment (tangents, curves and spirals).

Without the maximum warp parameter, the regulation on crosslevel alone may not be sufficient. Consider rails with a positive crosslevel followed by a negative crosslevel followed by a sequence of alternating positive and negative crosslevels. Although, all of those crosslevels are in permissible parameter, when operating a train along such track, the motion will be rocking left and right. Therefore, the maximum warp parameter is used to prevent the critical harmonic rock-off condition that may result in the trains rocking back and forth and derailing following wheel climb.

In the United States, the specific distance used for measurement to ensure that the difference in crosslevel of the track is within the permissible warp parameter is 62 feet. The design warp is zero for both tangent and curved track. That means, ideally, the crosslevel should not change between any two points within 62 feet. There are some deviations to allow crosslevels along the track to change (such as change for superelevation in curves). Different levels of those deviations from the zero warp specify the speed limits.

The specification that focuses on the rate of change in crosslevels of curved track is contained within the area related to cant gradient.

Longitudinal

elevation Track

gradient

The term **track gradient** is relative elevation of the two rails along the track. This can be expressed in the distance traveled horizontally for a rise of one unit, or in terms of an angle of inclination or a percentage difference in elevation for a given distance of the track.

The allowable gradients may be based on the **ruling gradient** which is the maximum gradient over which a tonnage train can be hauled with one locomotive. In some countries, **momentum gradient** which is a steeper but shorter gradient may be allowed. This is usually when there is a track gradient is connected to a leveled tangent track that is long enough with no signal between them so that train can build momentum to push through steeper grade than it can be without momentum.

In curved track (with or without cant), there will be curve resistance to push the trains through the curve. The allowable gradients may be reduced on curves to compensate for the extra curve resistance. The gradient should be uniform along the track.

Vertical curve

Vertical curve is the curve in vertical layout to connect two track gradients together whether it is for changing from an upgrade to a downgrade (summit), changing from a downgrade to an upgrade (sag or valley), changing in two levels of upgrades or changing in two levels of downgrades.

Some countries do not have specification on the exact geometry of vertical curves beyond general specification on vertical alignment. Australia has specification that the shape of vertical curves should be based on quadratic parabola but the length of a given vertical curve is calculated based on circular curve.

Curvature

In most countries, the measurement of curvature of curved track is expressed in radius. The shorter the radius, the sharper the curve is. For sharper curves, the speed limits are lower to prevent an outward horizontal centrifugal force to overturn the trains by directing its weight toward the outside rail. Cant may be used to allow higher speeds over the same curve.
In the United States, the measurement of curvature is expressed in degree of curvature. This is done by having a chord of 100 feet (30.48 m) connecting to two points on an arc of the reference rail, then drawing radii from the center to each of the chord end points. The angle between the radii lines is the degree of curvature.[7] The degree of curvature is inverse of radius. The larger the degree of curvature, the sharper the curve is. Expressing the curve in this way allows surveyors to use estimation and simpler tools in curve measurement. This can be done by using a 62-foot (18.90 m) string line to be a chord to connect the arc at the gauge side of the reference rail. Then at the midpoint of the string line (at the 31st foot), a measurement is taken from the string line to the gauge of the reference rail. The number of inches in that measurement is approximated to be the number of degrees of curvature.

Due to the limitation of how specific train equipment can make a turn at maximum speeds, there is a limitation of minimum curve radius to control the sharpness of all curves along a given route. Although most countries use radius for measurement of curvature, the term maximum degree of curvature is still used outside of the United States such as in India, but with the radius as the unit.

CANT

In curved track, it is usually designed to raise the outer rail, providing a banked turn, thus allowing trains to maneuver through the curve at higher speeds that would otherwise be not possible if the surface was flat or level. It also helps a train steer around a curve, keeping the wheel flanges from pressing the rails, minimizing friction and wear. The measurement of the difference in elevation between the outer rail and the inner rail is called cant in most countries. Sometime the cant is measured in term of angle instead of height difference.[9] In the United States, it is measured in height difference and called crosslevel, even for the curved track.

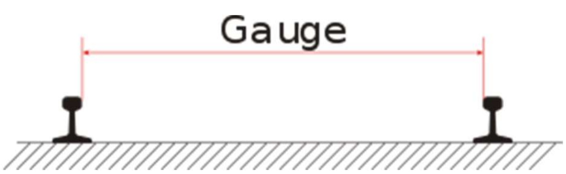
When the outside rail is at higher elevation than the inside rail, it is called positive cant. This is normally the desired layout for curved track. Most counties achieve the desired level of positive cant by raising the outside rail to that level which is called superelevation. For Swiss railroads, the cant is done by rotating at the track axis (center of the two rails) to have outside rail super elevated (raised) at the half rate of the desired cant and the inside rail under elevated (lowered) at the same half rate of the desired cant.

When the outside rail is at lower elevation than the inside rail, it is called negative cant (or reverse crosslevel in the United States). This is not usually a desired layout but it may be unavoidable in some situations such as curves involving turnouts.
There are regulations which limit the maximum cant. This is to control the unloading of the wheels on the outside rail (high rail), especially at low speeds.

CHAPTER-3 RAIL GAUGE

Introduction

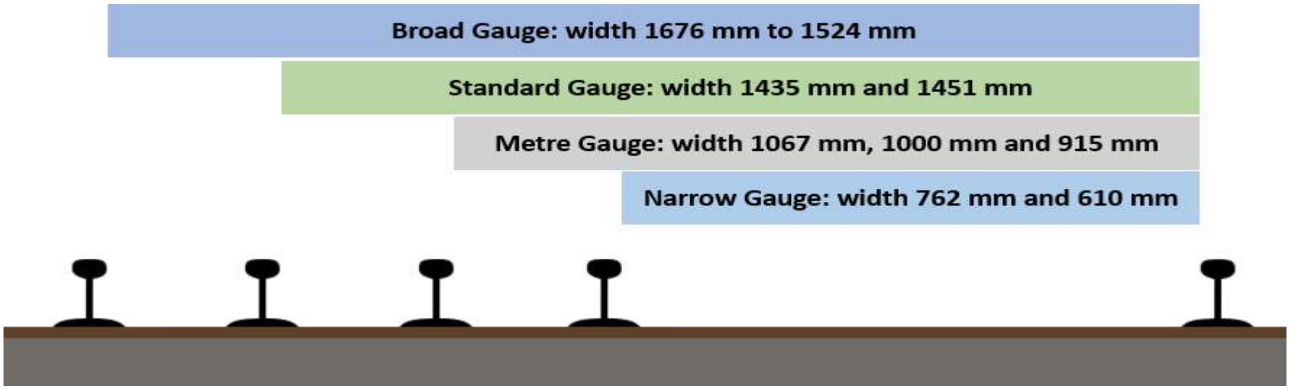
Rail gauge is the distance from the inside of one rail on a railroad track to the inside of the other. Most tracks use a standard gauge of 1,435 mm (4 ft, 8 1/2 in). Wider gauges are called broad gauge, smaller gauges are called narrow gauge. Broad gauge may be used where the track needs to have big things moving on it. Narrow gauge, such as metre gauge, is used to build railroads for less money, because the smaller track costs less. Places where different gauges meet are called break of gauge.



Types of Rail Gauges

The different gauges can broadly be divided into the following four categories:

1. Broad Gauge: width 1676 mm to 1524 mm or 5’6” to 5’0”
2. Standard Gauge: width 1435 mm and 1451 mm or 4’-8¹⁄2”
3. Metre Gauge: width 1067 mm, 1000 mm and 915 mm or 3’-6”, 3’-33/8” and 3’-0”
4. Narrow Gauge: width 762 mm and 610 mm or 2’-6” and 2’-0”.



Following are the factors affecting the choice of a gauge:

1. Traffic Condition: If the intensity of traffic on the track is likely to be more, a gauge wider than the standard gauge is suitable.
2. Development of Poor Areas: The narrow gauges are laid in certain parts of the world to develop a poor area and thus link the poor area with the outside developed world.
3. Cost of Track:

a. The cost of railway track is directly proportional to the width of its gauge.

b. If the fund available is not sufficient to construct a standard gauge, a metre gauge or a narrow gauge is preferred rather than to have no railways at all.

4. Speed of Movement:

a. The speed of a train is a function of the diameter of wheel which in turn is limited by the gauge.

b. The wheel diameter is usually about 0.75 times the gauge width and thus, the speed of a train is almost proportional to the gauge.

c. If higher speeds are to be attained, the broad gauge track is preferred to the metre gauge or narrow gauge track.

5. Nature of Country:

a. In mountainous country, it is advisable to have a narrow gauge of the track since it is more flexible and can be laid to a smaller radius on the curves.

b. This is the main reason why some important railways, covering thousands of kilometers, are laid with a gauge as narrow as 610 mm.

Advantages and disadvantages of different track gauges

Narrow gauge railways usually cost less to build because they are usually lighter in construction, using smaller cars and locomotives (smaller loading gauge), as well as smaller bridges, smaller tunnels (smaller structure gauge) and tighter curves. Narrow gauge is thus often used in mountainous terrain, where the savings in civil engineering work can be substantial. It is also used in sparsely populated areas, with low potential demand, and for temporary railways that will be removed after short-term use, such as for construction, the logging industry, the mining industry, or large-scale construction projects, especially in confined spaces.

Broader gauge railways are generally more expensive to build, but are able to handle heavier and faster traffic.

750 mm narrow gauge railway in Waldenburg, Switzerland.

Meter gauge tracks, Istanbul nostalgic tramways, Turkey.

In approximately 55% of the world’s railways are used standard gauge (1435 mm).

Inclined lift with a gauge of 8.2 metres in Lärchwand Schrägaufzug.

CHAPTER- 4 RAILS

Definition of Rails

A rail is a steel bar extending horizontally between supports which is used as a track for rail road, cars or other vehicles.

Types of Rails

Rails can be divided in three types

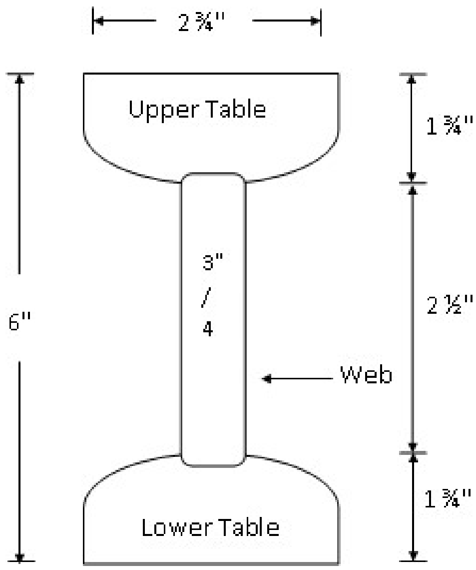
1. Double Headed Rails
2. Bull Headed Rails
3. Flat Footed Rails

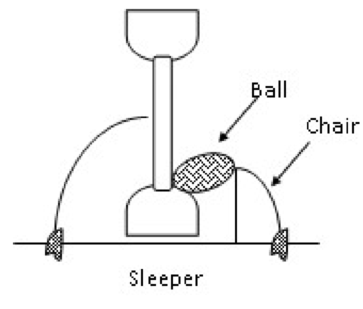
1. Double Headed Rails

These rails indicate the early stage of development. It essentially consists of three parts,

- Upper Table
- Web
- Lower Table

Both the upper and lower tables were identical and they were introduced with the hope of double doubling the life of rails. When the upper table is worn out then the rails can be placed upside down reversed on the chair and so the lower table can be brought into use. But this idea soon turned out to b wrong because due to continuous contract of lower table with the chair made the surface of lower table rough and hence the smooth running of the train was impossible. Therefore, this type of rail is practically out of use. Nowadays, these rails vary in lengths from 20 – 24. A 100 lb double headed rail is shown in the figure.



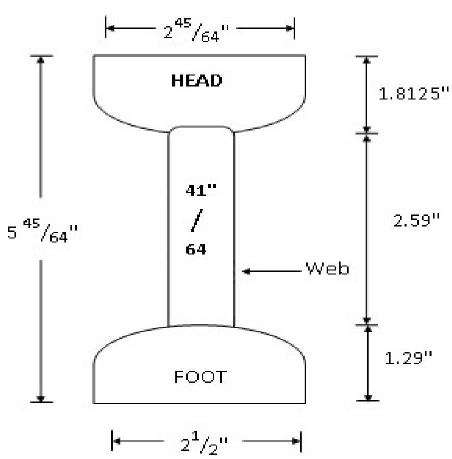


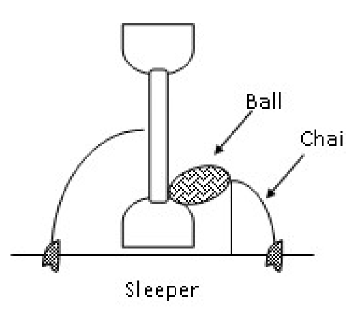
2. Bull Headed Rails

This type of rail also consists of three parts,

- The Head
- The Web
- The Foot

These rails were made of steel. The head is of larger size than foot and the foot is designed only to hold up properly the wooden keys with which rails are secured. Thus, the foot is designed only to furnish necessary strength and stiffness to rails. Two cast iron chairs are required per each sleeper when these rails are adopted. Their weight ranges from 85lb to 95lb and their length is up to 60 ft.



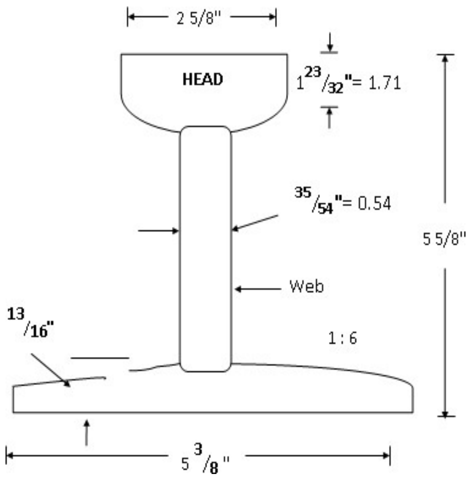


3. **Flat Footed Rails**

These rails were first of all invented by Charles Vignoles in 1836 and hence these rails are also called vignols rails. It consist of three parts

- The Head
- The Web
- The Foot

The foot is spread out to form a base. This form of rail has become so much popular that about 90% of railway tracks in the world are laid with this form of rails.



Flat footed rails has the following advantages

1. They do not need any chair and can be directly spiked or keyed to the sleepers. Thus they are economical.
2. They are much stiffer both vertically and laterally. The lateral stiffness is important for curves.
3. They are less liable to develop kinks and maintain a more regular top surface than bull headed rails.
4. They are cheaper than bull headed rails.
5. The loads from wheels of trains are distributed over large number of sleepers and hence larger area which results in greater track stability, longer life of rails and sleepers, reduced maintenance, costs, less rail failure and few interruptions to traffic.

Wear of Rails

The separation or cutting of rail due to friction and abnormal heavy load is called wear. There are three types of wears of rail.

1. Wear of Rails on top OR Head of Rail
2. Wear at the End of Rails
3. Wear at the side of head of Rails

Methods for Reducing Wear of Rails

The following methods are adopted for reducing wear of rails.

1. Use of Special Alloy Steel
2. Good Maintenance of Track
3. Reduction of Expansion Gap
4. Exchange of Inner and Outer Rails on Curves
5. Use of Lubricating Oil

Coning of Wheel

The rim or flanges of the wheels are never made flat but they are in the shape of a cone with a slope of about 1 to 20. This is known as coning of wheels. The coning of wheels is manly done to maintain the vehicle in the central position with respect to the track. When the vehicle is moving on leveled track then the flanges of wheels have equal circumference.

But when the vehicle is moving along a curved path then in this case the outer wheel has to cover a greater distance then that of inner wheel. Also as the vehicle has a tendency to move sideways towards the outer rail, the circumferences of the flanges of the inner wheel and this will help the outer wheel to cover a longer distance than the inner wheel. In this ways smooth riding is produced by means of coning of wheels.

Coning Wheels Disadvantages

Coning wheels has the following disadvantages:

1. In order to minimize the above below disadvantages the tilting of rails is done. i.e. the rails are not laid flat but tilted inwards by using inclined base plates sloped at 1 in 20 which is also the slope of coned surface of wheels.
2. The pressure of the horizontal component near the inner edge of the rail has a tendency to wear the rail quickly.
3. The horizontal components tend to turn the rail outwardly and hence the gauge is widened sometimes.
4. If no base plates are provided, sleepers under the outer edge of the rails are damaged.
5. In order to minimize the above mentioned disadvantages the tilting of rails is done. i.e. the rails are not laid flat but tilted inwards by using inclined base plates sloped at 1 in 20 which is also the slope of coned surface of wheels.

Advantages of Tilting of Rails

1. It maintains the gauge properly.
2. The wear at the head of rail is uniform.
3. It increases the life of sleepers and the rails.

RAIL CORRUGATION

Rail corrugation is a phenomenon of great diversity but appears now to be substantially understood. This review proposes some differences in classification of the phenomenon to take account of work undertaken since a widely cited review was published by Grassie and Kalousek in 1993, it attempts to fill holes in an overall understanding of the problem, and answers questions that remained open in 1993 and several that have arisen since. All types of corrugation that have been documented to date are essentially constant-frequency phenomena. By treating the vehicle—track system in its entirety, treatments are proposed that impinge upon track and vehicle design as well as upon the wheel—rail interface where corrugation appears. There is no neat solution to rail corrugation, but it can be treated comprehensively and in many cases also prevented by using products that are already commercially available. Since the frequency of common wavelength-fixing mechanisms varies roughly in the range 50—1200 Hz, trains travelling at different speeds can produce corrugation of substantially similar wavelength by different mechanisms in different locations. Although historical data can no longer be checked, this is the most likely explanation of the belief that rail corrugation was a substantially constant-wavelength phenomenon.

Rail Creep

Creep in rail is defined as the longitudinal movement of the rails in the track in the direction of motion of locomotives. Creep is common to all railways and its value varies from almost nothing to about 6 inches or 16cm.

Causes of Creep

The causes of rail creep can be broadly classified into two categories

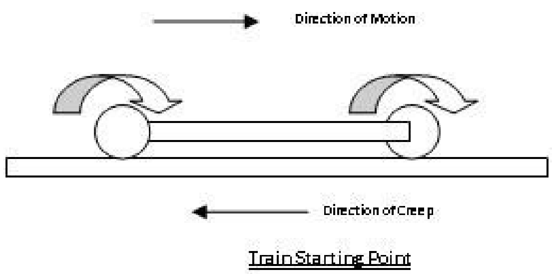
Major Causes o Creep

Minor Causes of Creep

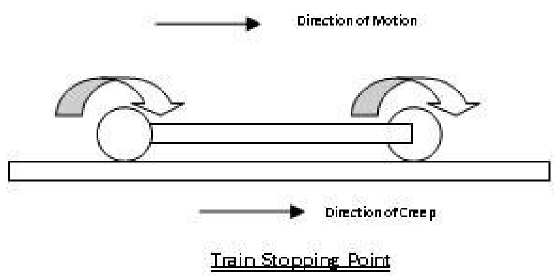
Major Causes of Creep

Major causes of creep also known as principal causes of creep. Follows are the major causes of creep in rail

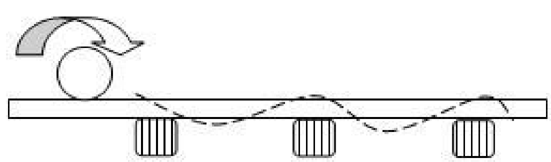
1. Creep may be developed due to forces that come into operation when the train is starting or stopping by application of brakes. Increase of starting the wheels pushes the rail backward and hence the direction of creep is in backward direction.



When brakes are applied then the wheels of the vehicles push the rails in forward direction and hence the creep is in forward direction.



2. Creep is also developed due to wave motions. When the wheels of the vehicles strikes the crests, creep is developed.



3. Another reason creep develops because of unequal expansion and contraction owing to change in temperature.

Minor Causes Creep

Some of the minor causes of creep in rail are below:

1. Rails not properly fixed to sleepers
2. Bad drainage of ballast
3. Bad quality of sleepers used
4. Improper consolidation of formation bed
5. Gauge fixed too tight or too slack
6. Rails fixed too tight to carry the traffic
7. Incorrect adjustment of super elevation on outer rails at curves

8. Incorrect allowance for rails expansion
9. Rail joints maintained in bad condition

Magnitude and Direction of Creep

Creep is not constant over a given period, it is not continue in one direction or at uniform rate. Both the rails of the track may creep in same direction, perhaps both the rails reverse the direction of creep or one rail creep in opposite direction to that of other

CHAPTER-5 RAIL FASTENINGS

Rail Fastenings

Any device used to secure running rails into chairs or baseplates or directly to sleepers, bearers or other rail supports. Rail fastenings keeps rails fastened to sleepers (transfer of forces), provides a proper slope of rail foot (1:20, 1:40) in the transverse plane, prevents the rail from longitudinal movement, damps noise and vibration coming from rails.

General Requirements for Rail Fastenings

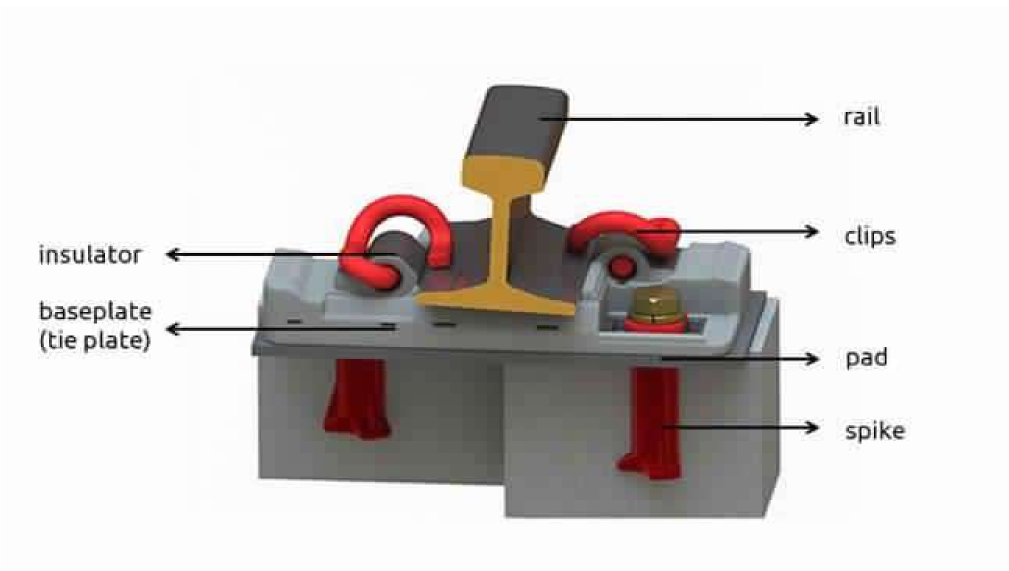
Rail fastenings shall:

1. hold rails securely in the rail seat.
2. limit the rotation of the rail about the outer edges of the rail foot.
3. minimise longitudinal movement of rails through creep and thermal forces.
4. assist in retention of track gauge.
5. not cause damage to the rail.

Where practicable, rail fastenings shall either be self-tensioning or permit tightening of the fastening to a predetermined load.

Where existing rail fastenings are not effective in minimising longitudinal movement of rails, it is permissible to fit rail anchors as a method of meeting this requirement.

Rail Fastenings Components



Clips

Clips are used to fasten the rails to the underlying baseplate.

Spike

Rail screw is a large (~6 in or 152 mm length, slightly under 1 in or 25 mm) metal screw used to fix a tie plate or fasten rail.

Tie Plate

A tie plate is also called a baseplate or sole plate. Rail tie plate is used in rail construction to support the rails. Tie plates are generally used to take the load of rail and distribute the load to the sleepers offering proven economies.

Insulator

Rail insulator is used to adjust rail gauge and insulate the rail from ties and clips.

Pad

The rail pad, originally called sole plate, is used when rail is attached to concrete, rather than timber, ties or sleepers. Rail pads function to reduce fatigue cracking of the concrete ties, believed to be driven by impact and vibration from the passing train.

The raid pad prevents rail-sleeper abrasion and the crushing of the sleeper under the rail foot. Rubber rail pads are normally designed to a specified load-deflection characteristic. The initial stiffness of the rail pad is designed to be low so that that their deformations under the springs toe loads is quite substantial. This ensures that the rail pad remains in intimate contact with the rail despite any vertical movements of the latter. When the wheel is over the pad, the latter's stiffness must be high to prevent large movements which can result in the metal spring becoming loose. Such a load-deflection characteristic can be obtained by introducing grooves in the rubber rail pads. Rubber pad or grooved rubber rail pad are made up of rubber or plastic to dampen the shocks of vibrations of a passing train.

Compatibility of Components

Components that are to be used together (including rail supports, rail fastenings, pads and rail foot insulators) shall be compatible.

Selection of Components

The selection of components shall take into account the following factors:

1. track geometry
2. permissible and enhanced permissible speeds
3. track category
4. loads arising from braking and acceleration of trains
5. vehicle axle loads
6. electrical insulation requirements
7. underlying formation and structures supporting the track
8. the form of track construction.

Fixtures And Fastenings:

Fixtures and fastenings are fitting to require for joining of rails end to end and also for fixing the rails to sleepers on a track.

FUNCTIONS OF FIXTURES AND FASTENINGS:

- To join the rails end to end to form full length of track
- To fix the rails to sleepers.

- To maintain the correct alignment of the track.
- To provide proper expansion gap between rails.
- To maintain the required tilt of rails.
- To set the points and crossings in the proper position.

All those fittings which are required for connecting the rails end to end and for fixing the rails to the sleepers in a track are known as fixtures and fastenings.

They include -
1) Fish plates
2) Spikes
3) Bolts
4) Chairs
5) Keys
6) Blocks
7) Bearing plates

The different functions of these fitting are :
1) To keep the rails in the proper positions.
2) Connection of rail to rail.
3) To set points and crossings properly
4) To allow for expansion and contraction of rails.

The various types of fixtures and fastenings listed above are briefly described below :

FISH PLATES : These plates are used to maintain proper alignment of the rail line. They maintain the continuity of the rails and also allow expansion or contraction of rails caused due to temperature variations. Generally these plates are made of mild steel and 20 mm in thickness.

They are 45.6 cm long and provided with 4 no. of 32 mm diameter holes at 11.4 center to center.

Indian railways generally adopt following two types of fish plates :-
1) Bone shaped fish plate
2) Increased depth fish plate

Bone shaped fish plate is used for connecting flat footed rails. The increased depth fish plate is generally used for connecting Bull-headed rails.

SPIKES : They are used to hold the rails to the wooden sleeper. A good spike should have following qualities :
1) It should have sufficient strength to hold the rail in position.
2) It should help in maintaining proper gauge.
3) It should be easy to fix and replace from the sleepers. Indian Railways use following types of spikes :-

1. Dog spikes
2. Screw spikes
3. Round spikes
4. Standard spikes
5. Elastic spikes

BOLTS : They are used for connecting :
1) Fish plates to the rails at each rail joint.
2) Chairs or bearing plates to timber sleepers.

3) Sleepers to bridge girders,etc

The different types of bolts used in Indian Railways are :

1. Hook bolts
2. Fish bolts
3. Fang bolts
4. Rag bolts

Hook bolts are used for fixing timber sleepers to bridge girders. They are popularly known as dog bolts.

Fish bolts are used to connect fish plates to the rails at rail joints.

Fang bolts are used for fixing side chairs to the sleepers.

Rag bolts are generally used to connect longitudinal timber sleeper or concrete sleepers to the walls of ash pits.

CHAIRS : They are used to hold the double headed and bull headed rails in required position. They are made of cast iron having two jaws and a rail seat. In order to fix the double headed or bull headed rail to a chair, the rail is placed between the two jaws of the chair.

KEYS : They are small tapered pieces of timber or steel to connect rails to chairs on metal sleepers.

Types of keys generally used are :

1) timber keys

2) metal keys

3) Stuart's keys

4) Morgan keys

BLOCKS : They are inserted in between the two rails running close to each other and bolted to maintain the required distance They may touch either the webs or the finishing faces or both.

BEARING PLATES : They are the plates placed in between the flat footed rails and timber sleepers on a track. They serve as chairs for flat footed rails. They are made of cast iron, wrought iron or steel.

Generally, they are of following types :

1) Flat bearing plates

2) canted bearing plates

Flat bearing plates are used at locations where rails are laid flat. Also they are used in turn out tracks under points and crossings.

Canted Bearing plates are used on soft timber sleepers beneath outside rail on curves, on sleepers placed on either side of rail joints, bridges etc. where rails are laid at an inward tilt of 1 in 20.

Ballast

Railway Ballast is the foundation of railway track and provide just below the sleepers. The loads from the wheels of trains ultimately come on the ballast through rails and sleepers.

Functions of Ballast

Some of the important functions of railway ballast are:

1. To provide firm and level bed for the sleepers to rest on
2. To allow for maintaining correct track level without disturbing the rail road bed
3. To drain off the water quickly and to keep the sleepers in dry conditions
4. To discourage the growth of vegetation
5. To protect the surface of formation and to form an elastic bed
6. To hold the sleepers in position during the passage of trains
7. To transmit and distribute the loads from the sleepers to the formation

8. To provide lateral stability to the track as a whole

Requirements for Ideal Ballast

The ideal material for ballast should fulfill the following requirements

1. It should be possible to maintain the required depth of the material in order to distribute the load of passing train on the formation ground
2. The material to be used for ballast should not be too rigid but it should be elastic in nature
3. The material for ballast should be of such nature that it grips the sleepers in position and prevent their horizontal movement during passage of train
4. It should not allow the rain water to accumulate but should be able to drain off the water immediately without percolating
5. It should be strong enough a resistance to abrasion

Materials for Ballast

The following materials are used for ballast on the railway track.

1. Broken Stone
2. Gravel
3. Cinders / Ashes
4. Sand
5. Kankar
6. Moorum
7. Brick Ballast
8. Selected Earth

CHAPTER-6 SLEEPERS

INTRODUCTION

Railway sleepers, also called railroad ties, railway ties or crossties, are an important railway component. Generally, the rail sleeper is always laying between two rail tracks to keep the correct space of gauge.

Having been developed for more than one hundred years, the railway ties need to meet the different requirements of the various railway tracks. In the past time, railroad ties were usually made of wood and had continued for about 50 years.

Then with the development of steel tracks, steel sleepers appeared. And later, the first concrete sleeper experiment was made in Germany in 1906 between the line Nuremberg and Bamberg.

In the recent time, concrete sleepers are widely used, especially in Europe and Asia. And in UK, steel ties are common. Besides, plastic composite ties are also employed in the rail track transportation.

Historically, wooden ties were made of a variety of softwood and some popular hardwoods such as oak, jarrah, and karri. They are only suitable for low-speed lines with a speed limit of 160 km/h. As to acceptable species of wood for sleepers, the types are European oak, beech, pine etc. But nowadays, wooden sleepers are mostly replaced by concrete sleepers in some countries.

Wooden sleeper advantages:

- Easy to manufacture and handle
- Electrically insulated
- Easily adapted to non-standard situations

Disadvantages:

- Non reusable
- Expensive of the limit wood resource

In recent times, steel sleepers mostly handle heavy loads and can be designed to suit different rail track specifications. Weighing the same as timber, steel sleeper can replace wood sleepers and be used on a ballasted bridge, providing a more durable and stronger solution without increasing bridge load.

Steel sleeper advantages:

- Easy to install and manufacture
- Handle more weight

Disadvantages:

- Sensitive to the chemical attacks
- Hard to maintain
- Low transverse resistance

Compared with wooden sleepers, which are increasingly difficult and expensive to source in sufficient quantities and quality, concrete ties are cheaper and easier to obtain.

In general, it can also be divided into pre-stressed mono block concrete sleepers and reinforced twin block concrete sleepers. Due to the greater weight, which helps sleepers remain in the correct position longer, concrete ties require less maintenance than timber and have a longer service life.

In some countries, concrete sleepers occupy an important position. For example, on the highest line categories in the UK, pre-stressed concrete ties are the only ones permitted by Network Rail standards.

Concrete sleeper advantages:

- Cheaper
- Easier to obtain
- Less maintenance required
- Longer service life

Disadvantages:

- Hard to handle due to large weight
- Difficult to maintain longitudinal level due to higher inertia moment and lower elasticity

1. Wooden Sleepers

These are commonly 254mm wide by 127mm thick in cross section by 2600 mm long. The sleepers are first seasoned (drying for up to 12 months so that to remove the juice/sap) and treated with preservative. Creosote is an oil generally used/ sprayed on the surface. They are either hard wood or soft wood type.

Wooden sleepers are the ideal type of sleeper. Hence they are universally used. The utility of timber sleepers has not diminished due to the passage of time.

Switch Ties: The primary use for switch ties is to transfer load (as from the name) and are made of hard wood. This type is preferably used in bridge approaches, heavily traveled, railway crossovers and as transition ties.

Softwood Ties: softwood timber is more rot (decay) resistant than hardwood, but does not offered resistance to spike hole enlargement, gauge spreading, also are not as effective in transmitting the load to the ballast section as the hardwood tie. Softwood ties and hardwood ties should not be mixed on the main track. Softwood ties are typically used in open deck bridges.

Concrete Ties: Concrete ties are rapidly gaining acceptance for heavy haul mainline use as well as for curvature greater than 2 degree. They are made of RCC or pre-stressed concrete containing reinforcing steel wires.

An insulator plate is placed between rail and tie to isolate the tie electrically.

Advantages of Wooden Sleepers

1. They are cheap and easy to manufacture
2. They are easy to handle without damage
3. They are more suitable for all types of ballast
4. They absorb shocks and vibrations better than other types of sleepers.
5. Ideal for track circuited sections
6. Fittings are few and simple in design
7. Good resilience
8. Ease of handling
9. Adaptability to non standard situation
10. Electrical insulation

Disadvantages of Wooden Sleepers

1. They are easily liable to attack by vermin and weather
2. They are susceptible to fire
3. It is difficult to maintain gauge in case of wooden sleepers
4. Scrap value is negligible
5. Their useful life is short about 12 to 15 years.

2. Steel Sleepers

- Steel ties are used where wood or concrete is not favorable, for example in tunnels with limited headway clearance
- They are also used in heavy curvature prone to gage widening.
- This type of steel ties can cause problem to signals control system
- Some problem of fatigue cracking have also experienced.
- Due to the increasing shortage of timber in the country and other economic factors have led to the use of steel and concrete sleepers on railways.

In the design of Steel sleeper, the following are considered:

- It should maintain perfect gauge
- Can fix the rail and there should be no movement longitudinally
- Should have sufficient effective area to transfer load from rail to ballast.
- The metal of sleepers should be strong enough to resist bending
- The design life should be 35 years

Advantages of Steel Sleepers

1. It is more durable. Its life is about 35 years
2. Lesser damage during handling and transport

3. It is not susceptible to vermin attack
4. It is not susceptible to fire
5. Its scrap value is very good

Disadvantages of Steel Sleepers

1. It is liable to corrosion.
2. Not suitable for track circuiting
3. It can be used only for rails for which it is manufactured
4. Cracks at rail seats develop during the service.
5. Fittings required are greater in number

3. Cast Iron Railway Sleepers

They are further divided into two categories:

1. Cast iron pot type sleepers
2. Cast iron plate type sleepers

Advantages of Cast Iron Sleepers

1. Service life is very long
2. Less liable to corrosion
3. Form good track for light traffic up to 110 kmph as they form rigid track subjected to vibrations under moving loads without any damping
4. Scrap value is high

Disadvantages of Cast Iron Sleepers

1. Gauge maintenance is difficult as tie bars get bent up
2. Not suitable for circuited track
3. Need large number of fittings
4. Suitable only for stone ballast
5. Heavy traffic and high speeds (>110kmph) will cause loosening of keys and development of high creep

4. Concrete Railway Sleepers

They have design life of up to 40 years. They can easily be moulded into the required/design shape to withstand stresses induced by fast and heavy traffic.

The added weight helps the rail to resist the forces produced due to thermal expansion and which can buckle the track. The weight of concrete sleepers is about 2.5 to 3 time the wooden sleepers. Pre-tensioned concrete sleepers are usually preferred now days

Reinforced Concrete and prestressed concrete sleepers are now replacing other types of sleepers except in some special circumstances like bridges etc. where wooden sleepers are used. Concrete sleepers may be of two types:

1. Mono Block Concrete Sleepers
2. TWIN BLOCK Concrete sleepers

Advantages of Concrete Sleepers

1. It is more durable having greater life (up to 50years)
2. It is economical as compare to wood and steel.
3. Easy to manufacture.
4. It is not susceptible to vermin attack
5. It is not susceptible to fire

6. Good for track circuited areas

Disadvantages of Concrete Sleepers

1. It is brittle and cracks without warning.
2. It cannot be repaired, and required replacement.
3. Fittings required are greater in number.
4. No scrap value

Bridges

Classification of Bridges

1.Classification of Bridges (According to form (or) type of superstructures)

•Slab bridge
•Beam bridge
•Truss bridge
•Arch bridge
•Cable stayed (or)suspended bridge

2.Classification of bridges (According to material of construction of superstructure)

•Timber bridge
•Concrete bridge
•Stone bridge
•R.C.C bridge
•Steel bridge
•P.C.C bridge
•Composite bridge
•Aluminum bridge

3. Classification of bridges (According to inter-span relationship)

•Simply supported bridge
•Cantilever bridge
•Continuous bridge

4. Classification of bridges (According to the position of the bridge floor relative to superstructures)

•Deck through bridge
•Half through or suspension bridge

5. Classification of bridges (According to method of connection of different part of superstructures)

•Pinned connection bridge
•Riveted connection bridge
•Welded connection bridge

6.Classification of bridges (According to length of bridge)

•Culvert bridge(less than 6 m)
•Minor bridge(less than 6 m-60m)
•Major bridge(more than 60 m)
•Long span bridge(more than 120 m)

9.Classification of bridges (According to function)

•Aqueduct bridge(canal over a river)
•Viaduct(road or railway over a valley or river)
•Pedestrian bridge
•Highway bridge
•Railway bridge
•Road-cum-rail or pipe line bridge

Bridge scour

It is the removal of sediment such as sand and rocks from around bridge abutments or piers.

Scour, caused by swiftly moving water, can scoop out scour holes, compromising the integrity of a structure.

Tunnels

A tunnel is an essentially horizontal, artificial underground opening, with a generally regular cross-section and a length that greatly exceeds its other dimensions. Tunnels are used for a wide variety of purposes. They **provide essential links in many highways, railroads, and urban rapid transit systems**.

Uses of Tunnels

Tunnels have many uses: **for mining ores, for transportation—including road vehicles, trains, subways, and canals—and for conducting water and sewage**.